Indian J. Phys. **81** (8), 787-792 (2007)

Analysis of ferrite based planar array of rectangular patch microstrip antenna in X-band

Madhurika Mahajan, Tapas Chakravarty and Sunil K Khah*

Department of Physics, Jaypee University of Information Technology, Waknaghat, Dist-Solan-173 215, Himachal Pradesh, India

E-mail sunil_khah@rediffmail com

Received 30 December 2006, accepted 18 July 2007

Abstract Analysis planar array of rectangular microstrip patch based on ferrite substrate has been carried out in X-band of Microwave Frequency range. The analysis is based on the vector wave function approach and pattern multiplication method Radiation characteristics like Patterns, Radiation conductance, Directive gain and radiated quality factor are computed and presented The results are significant and suitable for high frequency communication system.

Keywords · Planer array, microstrip antenna, ferrites

PACS Nos. 80 40 Ba, 52.40.Fd

1. Introduction

Printed microstrip antennas are widely used in phased-array application because they exhibit a very low profile, small size light weight, low cost, high efficiency, easy methods of fabrication and installation. Microstrip antennas highly suffer from an inherent limitation of narrow bandwidth. Array of elements is the remedy to the bandwidth limitation. Different types of arrays are used to enhance bandwidth [1–3]. The scanning of radiation properties can also be increased by changing the progressive phase difference between the elements. Microstrip antennas on ferrite substrate provide the ability to control the radiation characteristics of microstrip antennas [4]. In this communication the analysis of 4 × 4 planar array rectangular microstrip antenna is carried out. The antenna properties are computed for normally biased Ferrite substrate (YIG). For the comparison of the analyzed geometry, the same geometry is analyzed with RT Duroid substrate. It is observed that the antenna properties are enhanced considerably.

* Corresponding Author

2. Theory

The planar antenna array of rectangular patch and its co-ordinate system is shown in Figure 1. The array consists of equally spaced rectangular patches of length 'L' and width 'W' of height 'h' in a matrices pattern of 4 × 4.

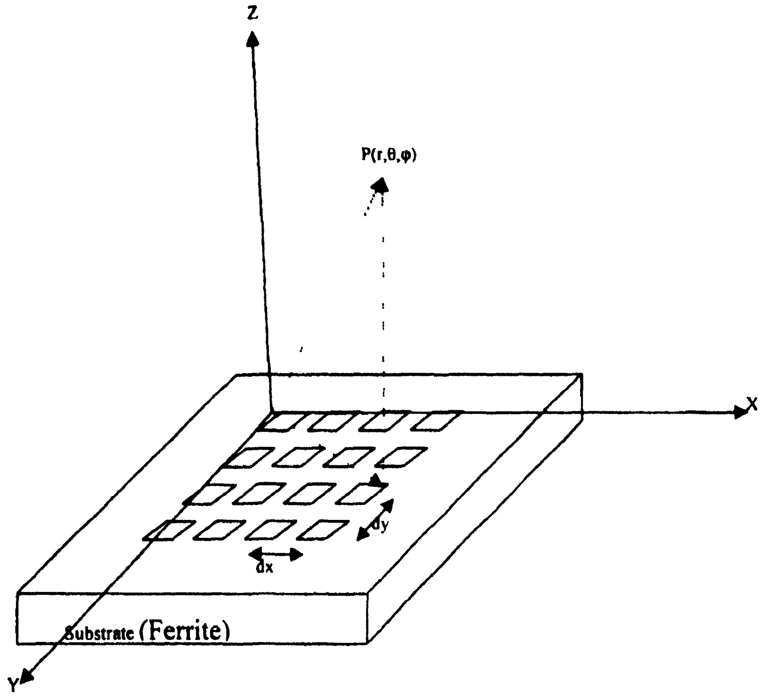

Figure 1. Geometry and co-ordinate system of array antenna.

The radiation field equations are obtained using vector wave function technique and pattern multiplication approach [2]. The total field equation are given as

$$E_{\theta t} = -j^{n}\frac{\exp(-j\beta_0 r)}{Z\lambda_0 r}4V_0 a\exp\left(j\frac{\beta_0 W}{2}\sin\theta\right)\times\cos\left(\frac{\beta_0 b}{2}\sin\theta\right)\times A.F. \qquad (1)$$

$$E_{\phi t} = j^{n}\exp\left(\frac{-j\beta_0 r}{Z\lambda_0 r}\right)4V_0 a\exp\left(j\frac{\beta_0 W}{2}\sin\theta\right)\times\frac{\sin\left(\frac{\beta_0 W}{2}\right)\cos\phi}{\left(\left(\frac{\beta_0 W}{2}\right)\sin\theta\right)\cos\phi}\times A.F. \qquad (2)$$

where $A.F.$ is the array factor for antenna.

2.1. *Field patterns :*

The total field patterns $R(\theta,\phi)$ is obtained from the relation

$$R(\theta,\phi) = |E_{\theta t}|^2 + |E_{\phi t}|^2 . \tag{3}$$

The value of $R(\theta,\phi)$ are computed for f = 10 GHz, $d_x = d_y = 1.5$ cm, $\beta_x = \beta_y = \frac{\pi}{2}$ and phase propagation constant k = 7.12 cm^{-1}. The results are calculated and plotted for rectangular planar array microstrip patch antenna with YIG substrate and RT Duroid.

2.2. *Radiation conductance :*

By integrating the poynting vector over a large sphere the expression for radiation conductance of the array geometry may be expressed as

$$G = \frac{2P_r}{V^2} \tag{4}$$

where P_r is the Power radiated for rectangular antenna

$$P = A' \int_0^{2\pi}\int_0^{\pi} \cos^2\left(\frac{\beta_0 W}{2}\sin\theta\right)\cos^2\left(\frac{\beta_0 W}{2}\sin\theta\right. \times (AF)^2 \sin\theta d\theta d\phi$$

here $$A' = -j^{2n}\frac{\exp(-2\,j\beta_0 r)}{Z_0^2\,\lambda_0^2 r^2} \times 16V_0^2 a^2$$

2.3. *Directive gain :*

The directive gain of the antenna in a given direction is defined as the ratio in radiation intensity U in the direction to the average radiated power P_r. It is expressed as

$$D_g = \frac{4\pi M_e}{I} \tag{5}$$

$$M_e = R(\theta,\phi) = |E_{\theta t}|^2 + |E_{\phi t}|^2 ,$$

$$I = \int_0^{2\pi}\int_0^{\pi} M_e \sin\theta \times d\theta \times d\phi .$$

2.4. Radiated quality factor :

Q_R is the total quality factor, given as

$$Q_R = 2\pi f_r \frac{W_T}{P_r} \tag{6}$$

where P_r is the radiated power, W_T is the total energy stored

and $$W_T = \frac{1}{2} \varepsilon_r \varepsilon_0 h \int |E_z|^2 dxdy \, .$$

3. Results

The results presented in this paper are for the operating frequency of 10 GHz. The ferrite substrate used is unbiased. The progressive phase excitation difference between the elements of array is taken as $\beta_x = \beta_y = \frac{\pi}{2}$. The dimensions are calculated for both ferrite and dielectric. The dimensions of the patch are given as (i) for ferrite (YIG) width 'W' = 0.5303 cm and length 'L' = 0.4412 cm, (ii) for dielectric (RT Duroid) are width 'W' = 1.936 cm and length 'L' = 1 cm. The height of the substrate is 'h' = 0.159 cm. For these input parameters the radiation patterns are calculated and plotted in Figures 2 and 3 for both substrates.

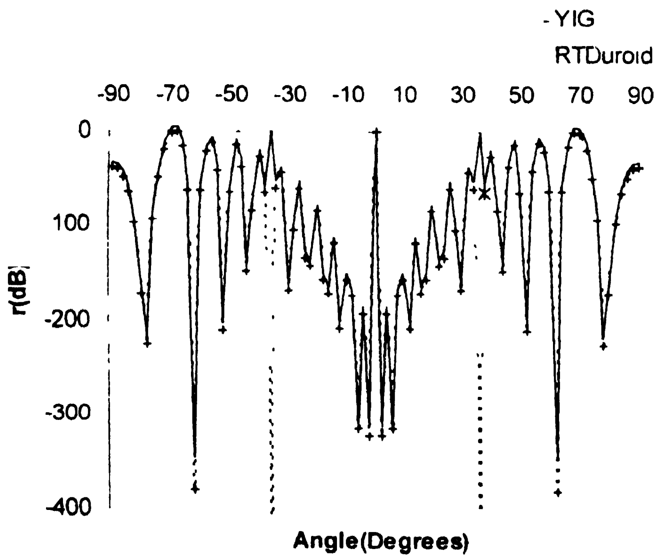

Figure 2. *E*-Plane field pattern of array (on both YIG and RT Duroid base).

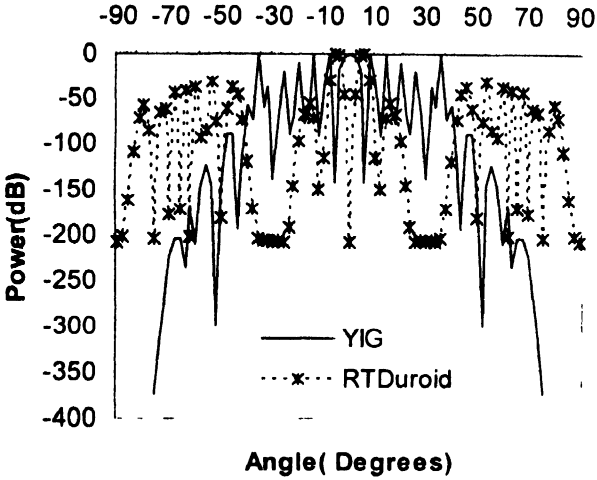

Figure 3. *H*-Plane field pattern of array (on both YIG and RT Duroid base).

Other radiation properties such as radiation conductance, directive gain and radiation quality factor are computed for YIG and are reported in Table 1. For comparison the same properties are computed and reported in the same table.

Table 1. Calculated values of antenna parameters of array geometry.

S.No.	Antenna parameters	Ferrite based array	Dielectric based array
1.	Dimensions of the patch (cm)	$W = 0.5303$	$W = 1.936$
		$L = 0.4412$	$L = 1$
2.	Radiation conductance (mho)	1.3×10^{-4}	4.3×10^{-5}
3.	Directive gain (dB)	3.95	2.31
4.	Radiated quality factor	231.07	31.26

4. Conclusions

The antenna designed on the YIG ferrite has shown enhanced properties over normal dielectric substrates. From the Table 1 it is evident that the size of the patch is considerably reduced when designed on ferrite substrate. This reduction would have a wide use in creating miniaturization of antenna. The field patterns change. There is marginal change in *H*-plane. But *E*-plane changes considerably. The numbers of minor lobes are reduced when designed on ferrite substrate. The radiation conductance, directive gain and radiation quality factor are enhanced considerably. Radiation conductance is multiplied by a factor of 3, directive gain is increased by a 35%, while as radiated quality factor is increased by a multiple of 7. From the results it is concluded that apart from conventional advantages of ferrites, the overall efficiency and characteristics of array are enhanced. These results are significant for design antenna setups for satellite communication.

References

[1] C B Balanis *Antenna Theory Analysis and Design* (New York : J. Wiley & Sons) (1982)

[2] I J Bahl and P Bhartia *Microstrip Antennas* (Norwood MA : Artech House) (1980)

[3] Sunil K Khah *Indian J. Phys.* **78B(1)** 71 (2004)

[4] P K S Pourush and L Dixit *IEE Proc. Microwave Antennas Propag.* **47** 2 (2001)